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ABSTRACT

The development and role of subject matter knowledge within teachers' professional development is currently the source of much research; however, the parallel development and role of pedagogical knowledge has yet to be systematically analyzed. In investigating this seldomly tapped area of concern, researchers involved 26 preservice science teachers (12-United States and 14-Taiwan) in a study that provided insights regarding the following questions: (1) What is the nature/appearance of preservice science teachers' subject matter and pedagogy knowledge structure?; (2) What is the source(s) of these knowledge structures?; (3) Are these knowledge structures stable during the student teaching experience?; and (4) What is the relationship between these knowledge structures and how do they relate to the act of teaching? Although significant differences exist in the teacher preparation programs experienced by the aforementioned teachers, several interesting comparisons were made: (1) both groups were hesitant about completing a questionnaire that required information regarding their subject matter understanding; (2) it was more difficult for the Taiwanese teachers to conceptualize pedagogy apart from their subject matter; and (3) these preservice science teachers were not presented with an overt or covert structure of subject matter as part of their content preparation. (ZWH)

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An International Investigation of Preservice Science Teachers' Pedagogy and Subject Matter Knowledge Structures

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An International Investigation of Preservice Science Teachers' Pedagogy and Subject Matter Knowledge Structures

Recent concerns about the quality of teacher education programs (Carnegie Forum, 1986; Holmes group, 1986; Kennedy, 1990) and the evaluation of teaching (Shulman, 1986; 1987) have focused attention on the subject matter knowledge and pedagogical knowledge of teachers. As a consequence, many states have increased subject matter requirements for admission to teacher education programs. These increased requirements have taken the form of mandatory degrees in subject matter and/or subject matter competency examinations (e.g., National Teacher Examination) for prospective teachers. Such changes in policy have been made in spite of the fact that prior attempts to relate quantitative oriented measures of what teachers know (e.g., GPAs, college credit hours, degrees attained) with measures of effective teaching have rarely produced relationships of strong, practical significance (Brophy & Good, 1986).

The results of previous research, however, have not caused educators and policy makers to abandon the rather intuitive notion that a teacher's subject matter knowledge necessarily influences classroom practice. Rather, it has been recognized that the "older" more quantitatively oriented research paradigms may not be sufficient to answer the questions concerning teachers' subject matter knowledge, its formation, and potential impact on classroom practice. Consequently, quantitative research approaches have yielded to more in depth

qualitative measures of teachers' conceptual frameworks of subject matter.

Recent attempts to explore teachers' conceptual understandings of subject matter have used a wide variety of approaches, notably including semantic networks, word associations, concept maps, and various versions of card sort tasks (Baxter, Richert, & Saylor, 1985; Hashweh, 1986; Hauslein & Good, 1989; Hauslein, Good, & Cummins, 1992; West, Fensham, & Garrard, 1985; West & Pines, 1985; White, 1985; Wilson, 1989; among others). Although such approaches are often used in concert with interview protocols, respondents are typically asked to organize and/or categorize topics or themes provided by the researcher in order to elucidate underlying subject matter structures. Although the data yielded by the aforementioned techniques are qualitative in nature, the structure imposed on data collection arguably compromises the benefits and purpose of using a qualitative research design. To date, relatively few studies have avoided the pitfalls of limiting subjects' representations of content knowledge to an a priori list of topics while assessing development over time.

A notable exception has been Morine-Dershimer's (1989) open-ended assessment of preservice teachers' conceptions of lesson planning and subject matter structures during a microteaching course. Over the duration of the course these teachers adjusted their subject matter structures to be more consistent with what and how they taught. In similar

investigations, Gess-Newsome and Lederman (1993) and Lederman, Gess-Newsome, and Latz (1994) assessed preservice science teachers' subject matter structures as they proceeded through a full academic year of subject-specific teacher preparation courses and their student teaching experience. The results indicated that the preservice teachers' subject matter structures were revised as a consequence of the act of teaching.

Although the development and role of subject matter knowledge within teachers' professional development is presently the source of much research and controversy, the parallel development and role of pedagogical knowledge, with few exceptions (Hoz, Tomer, & Tamir, 1990; Lederman, Gess-Newsome, & Latz, 1994; Morine-Dershimer, 1989), and the interaction of these two domains of knowledge has yet to be systematically analyzed. Furthermore, the nature and development of pedagogy and subject matter knowledge structures among international preservice science teachers is a totally unchartered area of investigation.

The purpose of this international investigation was to assess the nature, development and changes in preservice secondary science teachers' conceptions/knowledge structures of subject matter and pedagogy as they proceeded through their student teaching experience. In particular, this investigation attempted to answer the following questions: 1. What is the nature/appearance of preservice science teachers' subject matter and pedagogy knowledge structures? 2. What is

the source(s) of these knowledge structures? 3. Are these knowledge structures stable during the student teaching experience?, and 4. What is the relationship between these knowledge structures and how do they relate to the act of teaching? In addition to combined data analyses, each of the research questions was addressed with respect to similarities and differences between the two cultural groups represented in the sample.

For the purposes of this investigation, 'knowledge structure' refers to the knowledge an individual possesses and the manner in which this knowledge is organized. Our research definition is intentionally broad and it is recognized that we might be more accurate in describing our teachers' knowledge as "conceptions "(and at times we use the terms synonymously) of subject matter and pedagogy as opposed to formal knowledge structures. Whether the label "knowledge structure" or "conception" is preferred, such referents should not distract the reader from the primary focus of this investigation: the nature, development, and changes in preservice science teachers' knowledge of subject matter and pedagogy as they proceed through a professional teacher preparation program.

Design

Sample

Twelve preservice secondary science teachers (seven biology, three general science, one chemistry, one physics; seven males, five females) from the U.S. and 14 preservice teachers (seven physics, four biology, and two chemistry;

eight males, four females) from Taiwan were studied as they proceeded through their student teaching experiences. The U.S. students were completing a one year Master of Arts in Teaching (MAT) program and possessed at least a B.S. degree in their subject matter field (two had a M.S. degree and one a Ph.D.). The Taiwanese students were in their final year of a four year teacher preparation program at a Normal University. The Taiwanese preservice teachers possessed the equivalent of a B.S. plus 15 credit hours in their subject matter specialty. Consequently, all of the preservice teachers (U.S. and Taiwanese) possessed a level of subject matter knowledge well above that of the typical preservice teacher. Each of the preservice teachers was seeking initial certification.

There were significant differences between the teacher preparation programs experienced by the U.S. and Taiwanese preservice teachers prior to the student teaching experience, which may have contributed significantly to several of the noted differences between the two samples. The duration of the teacher preparation program for the U.S. preservice teachers was one year and consisted primarily of subject-specific pedagogy courses, with subject matter background required as a prerequisite to admission. Student teaching was completed during the third quarter of a four quarter program. The Taiwanese students proceeded through a four year teacher preparation program in which both subject matter and pedagogy are addressed throughout the four years. Student teaching was completed at the end of the fourth year. At the time of

student teaching, however, each of the groups of preservice teachers had received instruction in learning theories, teaching methods and strategies, microteaching, and participated in field-based practica.

The student teaching experiences also differed significantly between the two programs. The U.S. preservice teachers worked full time in a school setting and assumed full instructional responsibilities for 3-4 classes (two preparations). Full instructional responsibilities were assumed for a period of 10 weeks. The Taiwanese students worked full time in a school setting for only one month, during which they assumed full instructional responsibilities.

The researchers were well acquainted with the preservice teachers as a consequence of the two researchers' significant instructional responsibilities within the two programs. It is believed that the existing rapport between researchers and subjects served to facilitate the gathering of in depth and accurate data as opposed to serving as a hindrance.

Data Collection and Analysis

The case study design specified by Bogdan and Biklen (1982) was considered most appropriate for this investigation. In this particular instance, the case study focused on two culturally different groups of individuals who were proceeding through two distinctly different teacher preparation programs and student teaching experiences. Data was collected and analyzed in two phases. Of initial interest was whether preservice science teachers possess coherent conceptions

and/or structures of their subject matter specialty and pedagogy. This question was addressed primarily in **Phase I**. The additional questions proposed by this study were addressed in **Phase II**.

Phase I. Each subject was given approximately 30 minutes, two weeks prior to the beginning of student teaching, to answer the following questions:

1. What topics make up your primary teaching content area? If you were to use these topics to diagram your content area, what would it look like?
2. Have you ever thought about your content area in the way you have been asked to do so above?

One week later, each subject was asked to answer the same questions, but with "important elements/concerns of teaching" substituted for the phrase related to primary teaching content area. The preservice teachers were asked to answer Question #1 again immediately following the completion of student teaching. For the second administration of the questionnaires, Question #2 was replaced with: "Have your views changed? If so, how and why?"

The preservice teachers were assured that there were no right or wrong answers to the questions about subject matter and pedagogy and that their responses would in no way affect their grade in a particular course or progress through the program. Although 30 minutes was provided for the completion of each questionnaire, most students completed the questionnaire in 20-25 minutes. It should also be noted that

no specific methods of formatting or organizing the subject matter and pedagogy "diagrams" were suggested to the preservice teachers. For instance, they were not asked to diagram their topics in the form of a concept map or hierarchical structure. The specific wording of the questionnaire remained an unavoidable source of concern because there seemed to be no language alternatives which would not implicitly or explicitly direct the format and nature of the preservice teachers' responses. For example, the use of the words "topics" and "diagram" were seen as potentially undermining the intended flexibility of the questionnaire. Consequently, the oral instructions provided with the distribution of questionnaires emphasized our intent and associated language-use problem. In short, the preservice teachers were told that their descriptions of subject matter and pedagogy could focus on topics, themes, processes, strands, etc. and could be "represented" by use of a diagram, concept map, picture, description, or in any manner which felt comfortable.

Overall, it was felt that this methodology was superior to past attempts to assess subject matter and pedagogy knowledge structures because it gave respondents the freedom to select their own topics, themes, processes, strands, etc. (as opposed to card sorts) and to organize these elements of knowledge in any manner which felt comfortable (as opposed to artificially forcing representations into categories, hierarchies, dimensions, or particular formats). It was hoped that this

approach would provide a clearer portrait of the preservice teachers' conceptions/structures of subject matter and pedagogy. All representations and written text produced by the Taiwanese preservice teachers were translated into English prior to data analysis.

Qualitative analysis of the data collected during this phase (two administrations each of the subject matter and pedagogy questionnaires) attempted to derive any evident patterns among and within both groups of preservice teachers' stated subject matter and pedagogy structures. This initial analysis (conducted by the first author) served as a guide for additional data collection during a follow-up interview which occurred one to two weeks after the completion of student teaching.

Phase II. Within two weeks following the completion of student teaching an attempt was made to assess changes in the preservice teachers' knowledge structures and to clarify any patterns elucidated in **Phase I**. Each U.S. subject was asked to participate in a 45-60 minute videotaped interview conducted by the first author while the Taiwanese preservice teachers were interviewed by both researchers with one serving as translator. The interviews were guided by questions which asked the subjects to describe their current knowledge structures, discuss changes which had occurred and any reasons for these changes, discuss any relationships between the knowledge structures or between either knowledge structure and their teaching, and their feelings about completing the

questionnaire. During the interview, the previously completed knowledge structure diagrams/representations were displayed and discussed individually and as a group. Finally, all subjects were given an opportunity to revise the second diagram/representation produced for subject matter and pedagogy to conform to any changes which might have occurred since its completion.

Importantly, the interview was also viewed as a means to compensate for any confusion created by the paper-and-pencil questionnaire (either with respect to the respondents' reactions or the researchers' interpretations of responses). The problems associated with researchers' attempts to infer individuals' conceptions, knowledge, and beliefs solely from paper-and-pencil measures has been well recognized (Lederman, 1992). All interviews were transcribed (and translated when necessary) for analysis. Data were compared within and between individuals to derive any evident patterns for this particular group of preservice teachers.

Both phases of data analysis were conducted by the first author with the second author independently analyzing both the Taiwanese and U.S. preservice teachers' knowledge structure representations and videotaped interviews. The independent findings of the two researchers were compared, contrasted and discussed. This was a critical step in the analysis of data given the cultural differences between the two groups of preservice teachers as well as the researchers. There was no attempt to achieve total agreement between the perceptions of

the two researchers. Such an attempt would only have served to eradicate the richer understanding of data which is gleaned from the different perspectives brought to data analysis by the use of multiple researchers (Bogdan & Biklen, 1992; Eisner, 1991; Lincoln & Guba, 1985). The result was a clearly more comprehensive and deeper understanding of the preservice teachers' conceptions while at the same time protecting interpretations from being overly influenced by the perspective of one researcher (Lederman & Gess-Newsome, 1991; Miles & Huberman, 1984).

Results and Discussion

The results reported represent the culmination of several rounds of data analysis, by each of the two researchers, and will be organized in terms of the initial questions guiding the investigation.

What is the nature/appearance of preservice science teachers' subject matter and pedagogy knowledge structures?

Interview responses indicated that the preservice teachers were quite hesitant while completing the first (and sometimes the second) subject matter questionnaire. Many felt tentative or uncertain about what to write. They indicated that there was no problem understanding the question or task at hand, but rather they were hesitant about the content (and quality) of their responses as indicated by the following representative comments:

> "I knew what I was supposed to do. Still, you don't want to look like you don't know what you're talking about. I know my subject matter well, but i worry about communicating my knowledge to others." (U.S. Preservice Teacher)

> "Knowing your subject matter is important. It would be very bad if a teacher did not know his subject. I did not want you to think I did not know my subject." (Taiwanese Preservice Teacher)

In short, both groups of preservice teachers were concerned that the questionnaire was a test of their subject matter understanding. No similar hesitancy or concern was expressed with respect to the pedagogy questionnaire, but the Taiwanese preservice teachers expressed much difficulty in conceptualizing pedagogy apart from their subject matter.

> "I am to become a physics teacher. So, I do not know how to think of teaching separate from physics." (Taiwanese Preservice Teacher)

> "This was a lot easier than the other questionnaire. I've seen so many teachers in my life, it's pretty easy to figure out what it's about." (U.S. Preservice Teacher)

Initial subject matter representations were primarily listings of discrete topics or science courses taken at the

university. The Taiwanese group, however, consistently included various pedagogical concerns (e.g., teaching approach, level of students) within their subject matter representations. The inclusion of pedagogical concerns within the subject matter representations of the Taiwanese preservice teachers was a consistent pattern throughout the investigation, serving to further reinforce the inability of the Taiwanese group to separate conceptions of subject matter from the teaching of the subject matter. The pedagogy structures were primarily listings of the teacher-oriented components of instruction. Student-oriented components of instruction (such as motivation, prior knowledge) were given little or peripheral attention by the U.S. group while the Taiwanese preservice teachers consistently placed the student as a focal point. The presence of integrative curriculum themes (e.g., nature of science, S-T-S) or connections between or within the components of either subject matter or pedagogy structures was not common for either group of preservice teachers. Again, it is important to note that the oral instructions provided with the questionnaires explicitly emphasized that the word "topics" need not be taken literally and that respondents could feel free to include topics, themes, processes, strands, etc. In addition, it was also emphasized that representations need not be "diagrams" and could take whatever form most accurately portrayed each individual's conceptions.

Organizational patterns were quite traditional with respect to subject matter. In general, subject matter structures were presented in three general formats: discrete (Figure 1), simple hierarchy (Figures 2 & 3), web-like (Figure 4). The Taiwanese sample overwhelmingly presented subject matter in the form of simple hierarchies (again, with pedagogical factors included) while their U.S. counterparts could be primarily characterized as striking a balanced between discrete formats and simple hierarchies. The web-like format was clearly not common within either group of preservice teachers. Naturally, the labels used to describe the appearance of subject matter representations were a matter of convenience. Of more significance are the clear distinctions among the representations as opposed to the descriptive labels.

Insert Figures 1, 2, 3, 4 Here

Pedagogy structures tended to be organized as web-like/interrelated representations of concerns, knowledge, and/or activities performed (Figure 5), with students conspicuously absent as a primary focus in the representations of the U.S. group (but as a clear focal point in the representations of the Taiwanese group) or as discrete "listings" of teacher focused responsibilities and instructional approaches (Figure 6). Again, descriptive labels are of convenience and should not distract from the

clear visual and substantive distinctions among representations.

Insert Figures 5 & 6 Here

What is the source(s) of these knowledge structures?

When asked about the source of their subject matter structures, many students admitted, as might be expected, that the portrayed elements and organizational scheme came from college courses and that the representations were only tentatively delineated without any conscious rationale. For example, comments consistent with the following were common:

> "I just put down the things we learned and did in my physics classes. Everything I know about physics comes from my teachers and books I have read." (Taiwanese Preservice Teacher)

> "How I view earth science is what I learned in school. Probably from all of my schooling, but mostly from what I had in college." (U.S. Preservice Teacher)

These findings suggest that preservice science teachers (regardless of nationality) are not being presented with an overt or covert structure (or global conceptual framework) of subject matter (or at least one that is recognized) as part of their content preparation. The reader is also reminded that both groups of preservice teachers possessed subject matter

knowledge backgrounds exceeding that included as part of an undergraduate degree in the U.S. Consequently, the lack of any recognizable subject matter structure does not appear to be unique to those with only undergraduate level preparation in subject matter. Given the recognized disconnected and fragmented manner in which college science courses are taught (Cheney, 1990), the results here are not very surprising. Unfortunately, this fragmented and discrete style of content presentation may be passed on, intact, as these preservice teachers attempt to teach courses at the secondary level.

When asked about the source of their pedagogy knowledge structures, the preservice teachers uniformly referred to introductory education courses and personal experiences as a student:

> "I have been a student and a student in education courses. Where else could I better learn about teaching?" (U.S. Preservice Teacher)

> "My science education courses at the university have taught me what I need to know to be a good teacher." (Taiwanese Preservice Teacher)

When students were asked if they had ever thought about their subject matter specialty or pedagogy in the manner requested by the questionnaire, only one of the U.S. preservice teachers, and none of the Taiwanese, admitted having previously thought of his subject matter in this manner. No individuals of either group admitted having done

so for their knowledge of pedagogy. Contrary to the findings of previous research which has relied on card sort tasks and other possibly restrictive assessment procedures (Baxter, et. al., 1985; Hashweh, 1986; Hauslein, Good, & Cummins, 1992; Hoz, et.al., 1990; Wilson, 1989), but consistent with research using more open-ended assessments (Lederman, Gess-Newsome, & Latz, 1994), these preservice teachers, appeared to possess no coherent, as typically defined by curriculum reform movements (Kennedy, 1990), or carefully considered structure for subject matter. Furthermore, the topics, themes, processes, etc. used in the representations by this group of preservice teachers exhibited little resemblance to the a priori elements/topics used in previous investigations. Perhaps, the more directed approaches (e.g., concept maps, card sort tasks, semantic maps) used in previous investigations of subject matter structures served to create the resulting structures (with respect to both content and organization) as opposed to providing an objective assessment. With respect to pedagogy, the results of this investigation were consistent with those obtained in previous investigations (Lederman, Gess-Newsome, & Latz, 1994; Morine-Dershimer, 1989).

Are these knowledge structures stable during student teaching?

Overall, virtually no changes were noted in the subject matter representations of either group. Although changes were clearly noted in the pedagogy knowledge structures of the U.S. group, the representations of the Taiwanese group remained quite stable. The lack of change in subject matter

conceptions of either group, in response to the planning and implementation of lessons during student teaching is a finding which contradicts an emerging, but consistent body of literature (e.g., Hauslein, Good, & Cummins, 1992; Gess-Newsome & Lederman, 1993; Lederman, Gess-Newsome, & Latz, 1994). When asked to discuss their conceptions of subject matter during the interview, typical responses clearly reinforced the impression provided by the written representations.

> "How I view biology really hasn't changed much. I pretty much think of things the same as I said before." (U.S. Preservice Teacher)

> "I am probably a bit more frustrated than before I taught. But I still view the teaching of physics the same." (Taiwanese Preservice Teacher)

The interviews definitively indicated that these preservice teachers had not altered their views of subject matter in response to the use of subject matter in the context of teaching. Of particular interest here is the Taiwanese preservice teacher's reference to "the teaching of physics." The representation and related discussion was intended to be limited to subject matter. However, as mentioned before, the Taiwanese preservice teachers consistently exhibited a subconscious difficulty or unwillingness to consider subject

matter as separate from the teaching of the subject matter. The significance of this clear difference from the U.S. preservice teachers will be addressed in the Implications section of this paper.

Pedagogy representations became increasingly more complex for the U.S. preservice teachers. A proliferation of student focused components (e.g., motivation, learning styles, relevancy, etc.) as well as additional teacher roles (e.g., friend, counselor) and responsibilities were clearly evident. Of most significance was a general shift away from linear representations of pedagogical knowledge to more web-like frameworks which placed the students and their concerns at the center (Figures 7 & 8). For example, the individual who created Figure 7 had initially created Figure 6.

Insert Figures 7 & 8 Here

In general, the pedagogy representations of the Taiwanese preservice teachers remained the same as before student teaching. In short, the representations of the U.S. preservice teachers became more similar to the initial and stable representations of their Taiwanese counterparts. The changes in representations of pedagogy by the U.S. group appeared to be influenced by the planning and implementation of actual lessons. A common explanation for the change in the U.S. preservice teachers' pedagogy structures is illustrated by the following comments:

> "The students demand your attention. You couldn't ignore them if you wanted to." (U.S. Preservice Teacher)

> "You can talk about the importance of the students all you want. You may even believe you have a focus on students' needs. But it's all abstract until you're actually face to face with 30 of them." (U.S. Preservice Teacher)

In short, the U.S. preservice teachers reinforced one of the commonly voiced shortcomings of campus-based teacher preparation courses. It is interesting to note, however, that the Taiwanese preservice teachers initially placed students as a focal point in their pedagogy structures and continued to do so throughout the duration of the investigation.

What is the relationship between these knowledge structures and how do they relate to the act of teaching?

During the interview the preservice teachers were asked to discuss and relate the set of four questionnaires (two subject matter and two pedagogy). Whenever overlaps or similarities between the two types of structures were noted, the subjects were asked if they could be combined into one diagram or whether a combined depiction would be more accurate. The U.S. preservice teachers uniformly responded negatively:

> "It makes more sense to me to keep the two separate. After all, knowledge of subject matter and how you teach subject matter are two different things." (U.S. Preservice Teacher)

> "They're different things. When I teach I need to know my subject matter, but my knowledge of teaching tells me how to present what I know." (U.S. Preservice Teacher)

On the other hand, the Taiwanese students were clearly less willing to distinguish between subject matter and pedagogy. As noted previously, they continued to integrate pedagogy into their conceptions of subject matter:

> "There is much overlap, of course. I have learned science because I wanted to become a science teacher. I learned science always with a view of teaching it." (Taiwanese Preservice Teacher)

The U.S. preservice teachers clearly perceived pedagogy and subject matter knowledge as separate entities which were applied in an integrated manner during teaching, while the Taiwanese preservice teachers perceived the two in a much more integrated manner. During the interview, individuals were provided with a hypothetical teaching situation in which

students are unable to understand a particular aspect of subject matter. When asked about what their response would be, the two groups of preservice teachers described their decision making process quite differently:

> "If students do not understand, I must find where the confusion is. To do this involves my knowledge of physics teaching. It is not a problem of subject matter or pedagogy." (Taiwanese Preservice Teacher)

> "High school students do not really know much biology. If they do not understand something, I must rely primarily on my knowledge of teaching. My knowledge of subject matter is important, because it gives me alternative examples to use, but it is my knowledge of teaching that lets me choose the correct solution to the problem." (U.S. Preservice Teacher)

In short, even when presented with a hypothetical classroom situation/problem, the U.S. group tended to conceptualize the influence of subject matter knowledge and pedagogy separately while their Taiwanese counterparts exhibited a more integrated approach to the two knowledge domains.

As previously mentioned, neither group of preservice teachers altered their conceptualizations of subject matter knowledge in response to their exposure to public school students and the planning and implementation of science lessons. This finding does not support prior suggestions

(Hauslein & Good, 1989; Hauslein, Good, & Cummins, 1992) that it may be impossible to view subject matter as separate from the manner in which it is, or will be used. The act of teaching and/or thinking about how one will teach subject matter did not appear to have a significant influence on the way subject matter was conceptualized among these two groups of preservice teachers.

The pedagogy structures of the U.S. group were seen to shift toward a focus on student concerns following the student teaching experience. This finding is consistent with assertions made by Lederman and Gess-Newsome (1991) concerning the shift in concerns of preservice science teachers toward students as soon as they begin to conduct lessons in actual field settings.

When specifically asked if their stated subject matter and pedagogy knowledge structures were evidenced in their teaching, both groups of preservice teachers were confident that each type of knowledge (i.e., subject matter and pedagogy) was reflected in how and what they taught:

> "Of course, at least I hope, my teaching is based on what I know and think." (Taiwanese Preservice Teacher)

> "I teach chemistry the way I view chemistry and I teach in a way that reflects my philosophy of teaching. I believe modeling to be very important in chemistry and it is continually stressed. I believe students

> learn best if they are actively involved and so I organize my class in that way."
> (U.S. Preservice Teacher)

These results are consistent with a large body of literature on the relation of subject matter structures and teaching (e.g., Baxter, et. al., 1985; Hashweh, 1986) and contradicts recent research (Gess-Newsome & Lederman, 1993; Hollingsworth, 1989) which indicates that preservice teachers are too overwhelmed by day-to-day instructional responsibilities to adequately and consciously incorporate integrated subject matter structures into daily instruction. The present results concerning the translation of subject matter and pedagogy knowledge structures into classroom practice must, however, be interpreted with extreme caution. The discrepancies between teachers' self-reports and actual classroom practices has been well documented. Additional research of this nature which includes actual classroom observations should be pursued.

Implications for Science Education

It does not appear these preservice science teachers, regardless of nationality, possess "well-formed" or highly integrated subject matter or pedagogy knowledge structures. Consistent with previous research (Gess-Newsome & Lederman, 1993; Hauslein, Good, & Cummins, 1992; Lederman, Gess-Newsome, & Latz, 1994), the subject matter knowledge structures which do exist are largely the result of college course work and are often fragmented and disjointed with little evidence of

coherent themes. Consequently, the currently popular policy of requiring increased subject matter backgrounds for preservice and inservice teachers, as a means to resolve the myriad of concerns about the quality of science instruction, may not be an effective approach. Such an approach, as seen with this group of preservice teachers, would most likely not lead to the development of the highly prized integrated subject matter conceptions advocated by the prominent science education reform movements (A.A.A.S., 1989; NSTA, 1993). Furthermore, the preservice teachers investigated in similar investigations (Gess-Newsome & Lederman, 1993; Lederman, Gess-Newsome, & Latz, 1994) possessed far less extensive backgrounds in science and were noted to develop more integrated subject matter structures in response to the planning and implementation of instruction. In addition, it is important to note that the U.S. preservice teachers studied in the present investigation completed the same professional teacher education coursework (e.g., methods, microteaching, practicum, etc.) as those in the studies by Gess-Newsome and Lederman (1993) and Lederman, Gess-Newsome, and Latz (1994), with the only difference being the extent of subject matter background (i.e., degrees and course credit hours). It is possible that the more extensive academic backgrounds of both the Taiwanese and U.S. preservice teachers (which is consistent with current teacher preparation reforms) may result in the development of more firmly entrenched and inflexible conceptions of subject matter. Consequently,

although few would argue with the desirability of science teachers with extensive academic backgrounds, it might be that present approaches to college level science instruction promote the development of relatively inflexible cognitive structures which are at odds with the integrated framework required for the implementation of the currently advocated curriculum reforms. Although possessing a relatively static view of one's subject matter as a consequence of more extensive academic background is a problem in need of solution, the situation is further exacerbated if the nature of the structure is less than desirable. Since any significant reform in the instructional approach which currently typifies college science teaching seems unlikely, the responsibility of stimulating students to reflect on their subject matter (in an effort to promote the development of more integrated knowledge structures) seems to be most appropriately placed within the domain of the science educator. It is possible that repeated opportunities to reflect on one's subject matter, as it is being learned, may be sufficient to provide preservice teachers with a coherent schema for their subject matter and allow them to integrate more of the information presented in their science courses. Certainly, the possible benefits to be derived from increased reflection upon subject matter within science education courses is an area needing further research.

The inability of the U.S. preservice teachers to present a coherent conceptualization of pedagogy prior to student

teaching is not surprising. As prior research has indicated (Lederman & Gess-Newsome, 1991), a well formed pedagogy knowledge structure should not be expected without actual experience with "real" secondary students. Other than simply increasing the length of field experiences (as many teacher education programs are already doing), it may be necessary to provide increased opportunities for preservice teachers to conduct systematic classroom observations (Good & Brophy, 1991) and reflect upon instructional sequences.

The U.S. and Taiwanese preservice teachers clearly conceptualized pedagogy, and the relationship of pedagogy and subject matter differently. Initially, the U.S. group gave students only peripheral attention while the Taiwanese group placed students as a focal point (a view the U.S. group adopted following student teaching). Furthermore, the Taiwanese group consistently exhibited difficulty in conceptualizing subject matter as separate from the teaching of the subject matter, while the U.S. group clearly preferred to keep subject matter knowledge and knowledge of pedagogy distinct. It appears that the distinct difference between the professional teacher education programs experienced by the two groups of preservice teachers may be responsible for the noted differences in conceptions of pedagogy and subject matter. In particular, the U.S. group was completing a MAT program. This program requires a B.S. degree (or beyond) in one's subject matter specialty for admission. The program does require an additional nine graduate hours in subject matter, but it is a

program primarily focused on science pedagogy with subject matter knowledge believed to have been achieved prior to entrance. In practice, virtually all of the U.S. preservice teachers had decided to become secondary science teachers during their senior year in college or following graduation. The Taiwanese group, on the other hand, had been educated in a system much like the U.S. Normal School. These students had decided to become teachers as they were completing their high school education and actually spent much effort preparing for entrance examinations which would enable them to attend a college dedicated to the preservice education of teachers. Consequently, the Taiwanese preservice teachers received their subject matter background concurrently with their teacher preparation, and the subject matter was typically presented with the perspective of eventually having to teach the subject matter to others. Although this was not an experimental investigation, it does not take much of an inference to see why the Taiwanese students initially focused on students when conceptualizing pedagogy (while the U.S. group did not) and experienced much difficulty in representing subject matter apart form the teaching of subject matter (while the U.S. group did not). Perhaps we need to reconsider the current U.S. trend toward graduate level teacher preparation, with subject matter knowledge "front loaded," with respect to the conceptions of pedagogy and subject matter which are apparently needed to implement the currently popular reforms.

Keeping in mind the caution necessitated by the fact that classroom observations of these preservice teachers were not performed, the self-reported influence of preservice teachers' subject matter structures on classroom practice is consistent with much of the research on pedagogical content knowledge (Gudmunsdottir & Shulman, 1987; Hashweh, 1986; Shulman, 1987). However, the resolve of U.S. preservice teachers concerning the separate application of subject matter knowledge and pedagogical knowledge to instructional decisions is at odds with the current thinking related to pedagogical content knowledge. Again, the Taiwanese preservice teachers were more integrated in their application of pedagogy and subject matter to classroom decisions. It may be that teacher preparation in a manner similar to the Normal University is more consistent with promoting pedagogical content knowledge than our current approaches to achieving this end.

The apparent contradiction of the findings related to subject matter structures with those of Gess-Newsome and Lederman (1993) is particularly intriguing. The subjects in their research included global, integrative (and arguably abstract) curriculum themes such as the nature of science and science-technology-society interactions in their subject matter structures. Such themes were virtually absent from the representations of both the U.S. and Taiwanese preservice teachers, rendering their knowledge structures to be relatively simple by comparison. Consequently, it is quite possible that the ease with which a subject matter structure

affects classroom practice (if at all) is as much a function of the relative complexity of the knowledge structure as it is related to curriculum constraints, administrative policies, management concerns, etc. Given that the data concerning translation of subject matter conceptions/structures into classroom practice was self-reported in nature, additional research which includes direct classroom observations should focus on the relationship between knowledge structure complexity and classroom practice. The possible importance of the complexity of one's knowledge structure is especially problematic since many of the new reforms in science education seem to depend on the incorporation of highly integrative themes such as the nature of science and science-technology-society interactions. If such highly complex and integrated subject matter structures are so difficult to translate into classroom practice, our expectations with respect to the ability of beginning and novice teachers' to implement curriculum reform may have to be drastically reconsidered.

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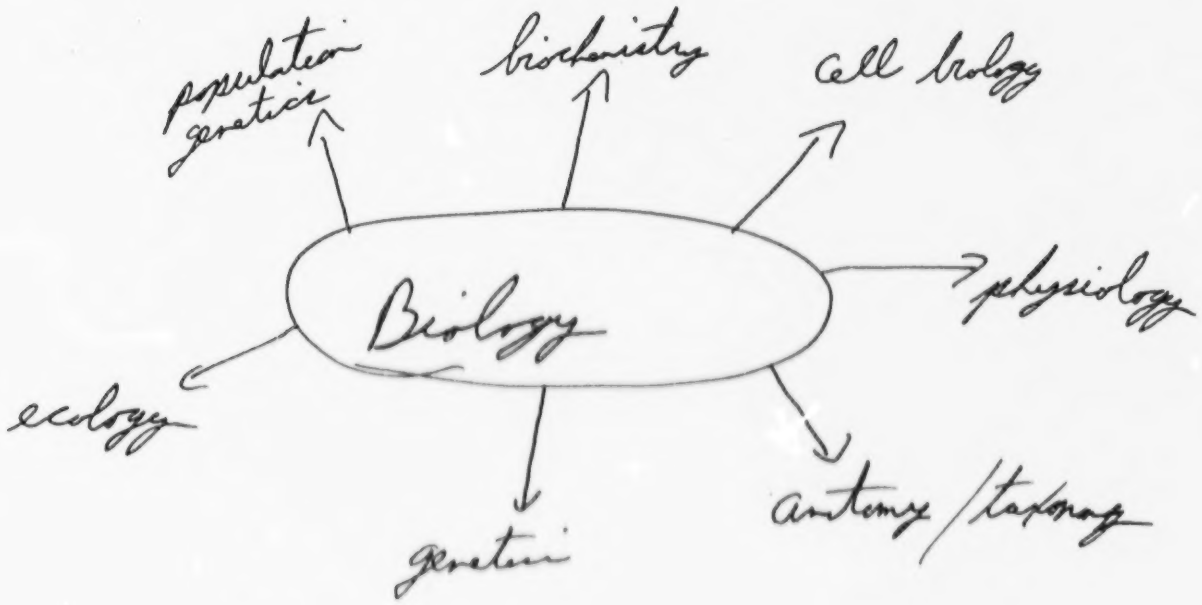

Figure 1. Discrete topics/course format for subject matter structure. (U.S. Preservice Teacher)

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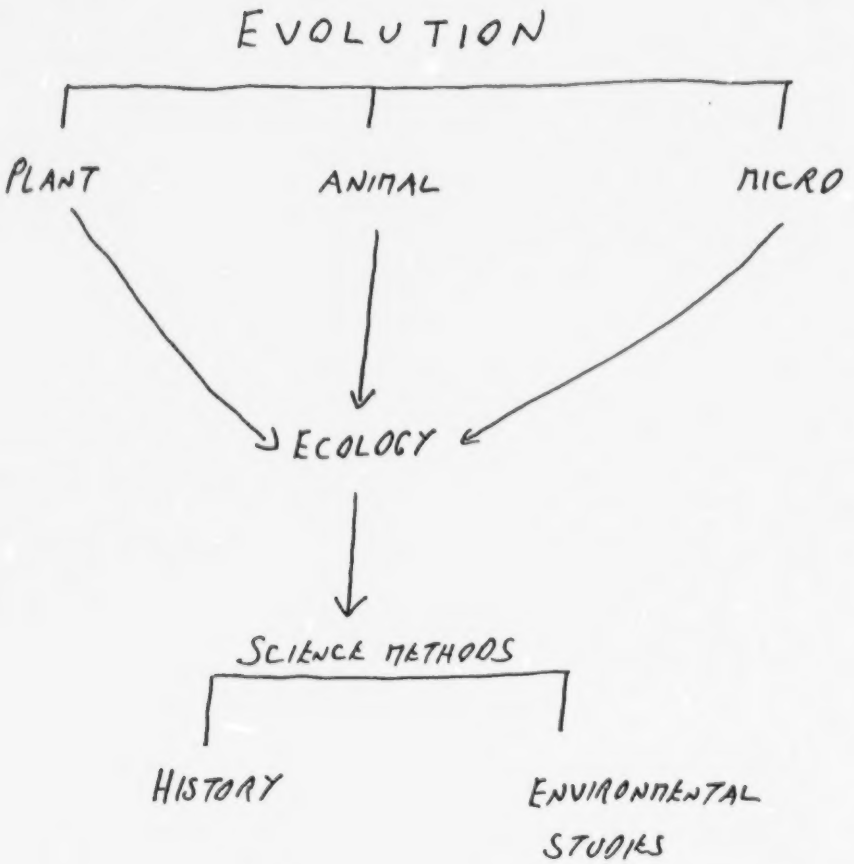

Figure 2. Simple hierarchy format for subject matter structure. (U.S. Preservice Teacher)

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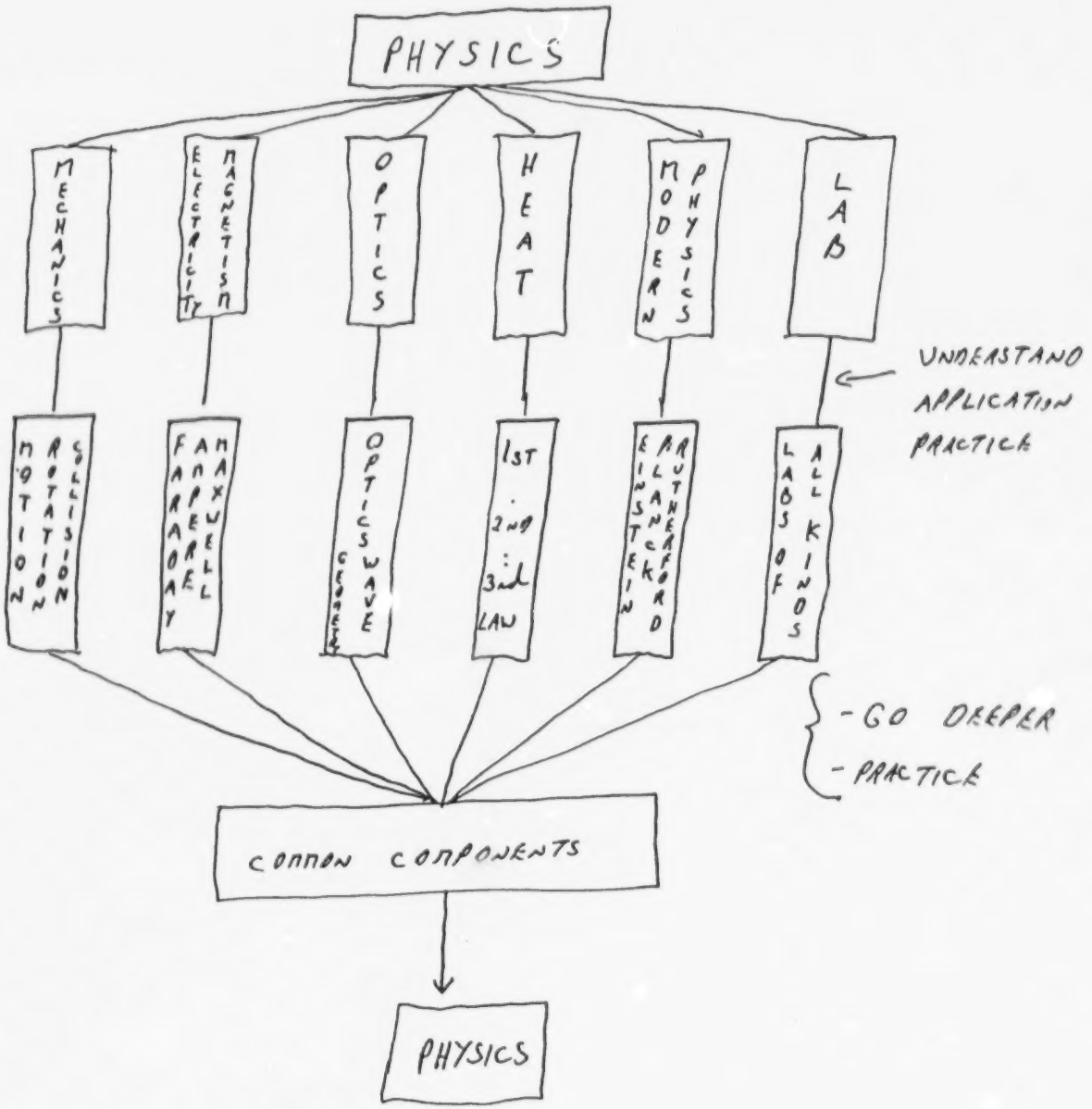

Figure 3. Simple hierarchy format for subject matter structure. (Taiwanese Preservice Teacher)

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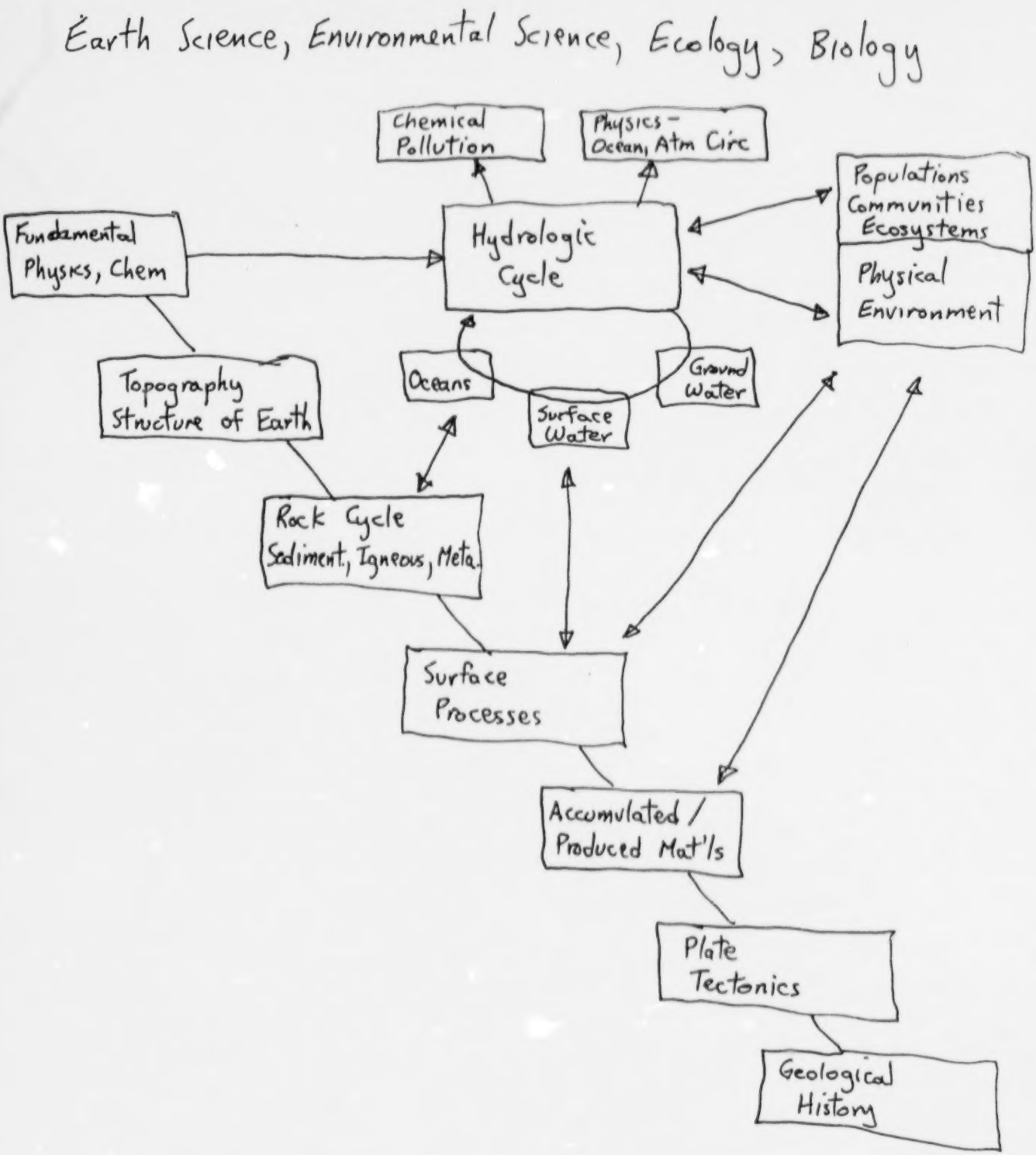

Figure 4. Web-like/interrelated format for subject matter structure. (U.S. Preservice Teacher)

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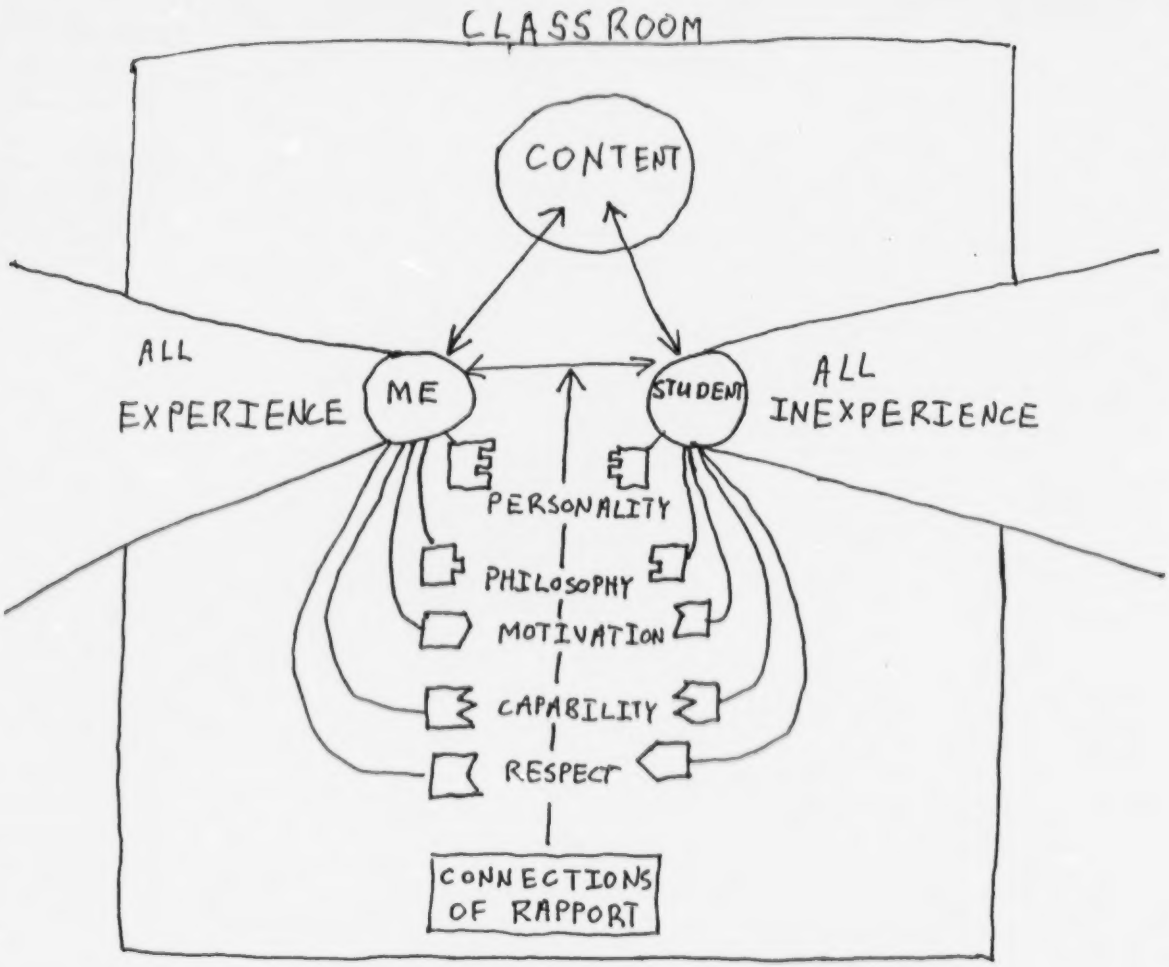

Figure 5. Web-like/interrelated format for pedagogy structure. (Taiwanese Preservice Teacher)

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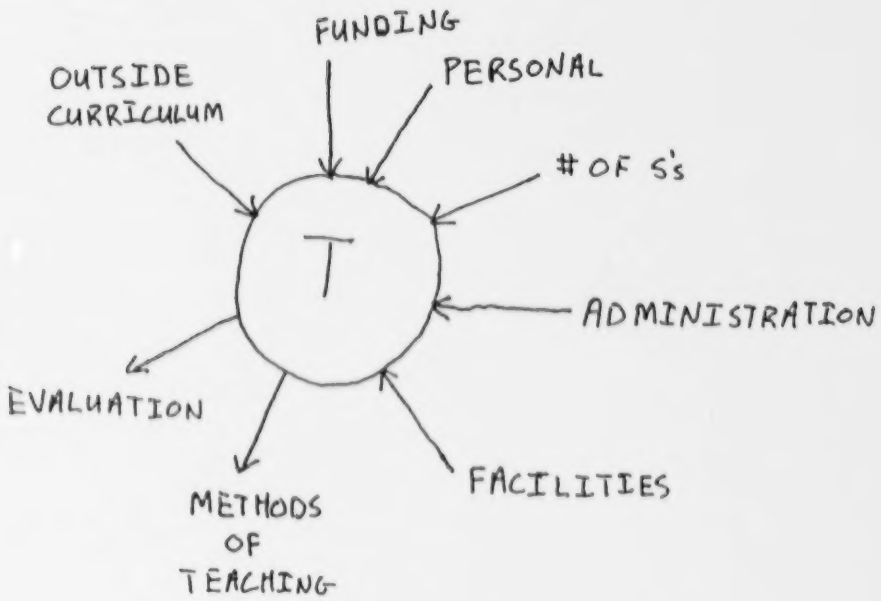

Figure 6. Discrete responsibilities/activities format for pedagogy structure. (U.S. Preservice Teacher)

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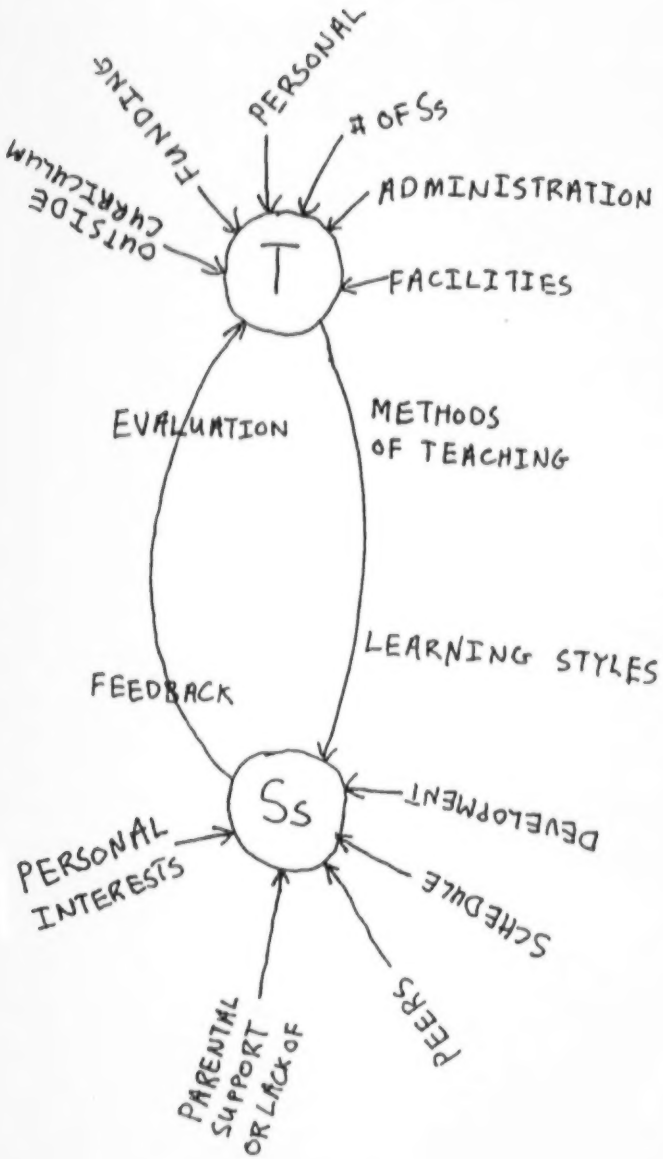

Figure 7. Web-like/interrelated format for pedagogy structure. (U.S. Preservice Teacher)

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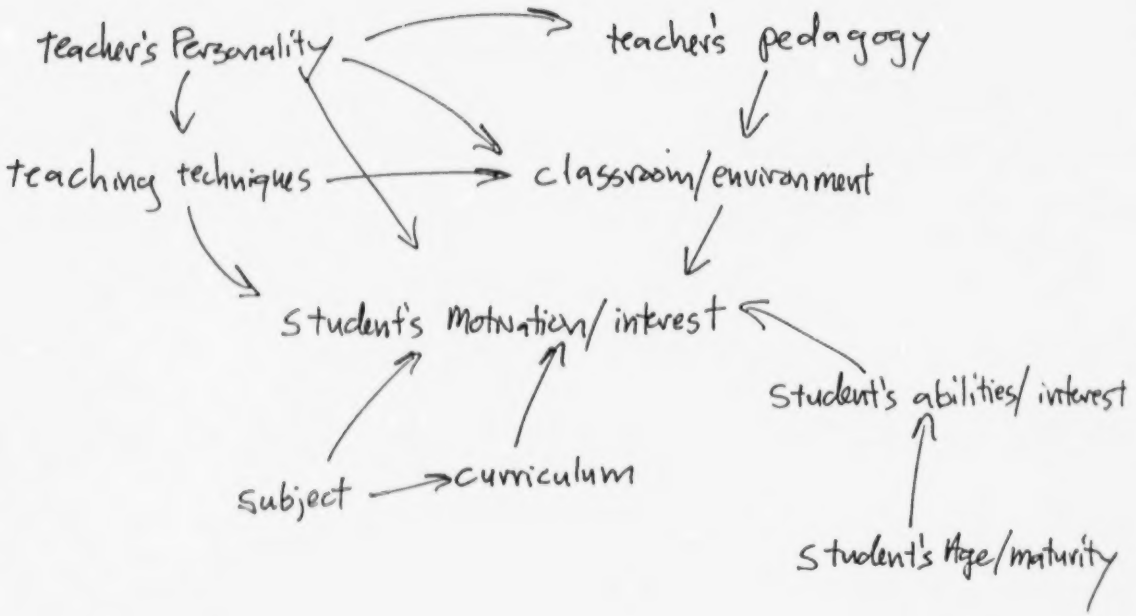

Figure 8. Web-like/interrelated format for pedagogy structure. (U.S. Preservice Teacher)

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